Advanced Information Technology Branch Modeling and Simulation Research

Code 5583 (Distributed Systems)
Naval Research Laboratory
Washington DC 20375

NAVMSMO Technical Interchange Meeting
19 August 2004

NRL 5583 M&S Research

- Advanced Information Technology Branch (AIT)
  - Code 5580: Branch Chief
  - Code 5580.1: *Special Projects Office*
  - Code 5581: *3-D Virtual and Mixed Environments*
  - Code 5583: *Distributed Systems*
  - Code 5584: *Intelligent Decision Support*
  - Code 5585: *Collaborative Engineering*

NRL 5583 M&S Research

- Subject Matter Expertise
  - Parallel Processing
  - Computer Science
  - Physics
  - Electrical Engineering
  - Mathematics
  - Visualization
  - Psychology and Physiology

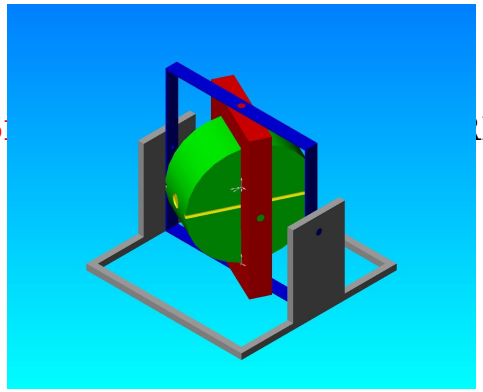
NRL 5583 M&S Research

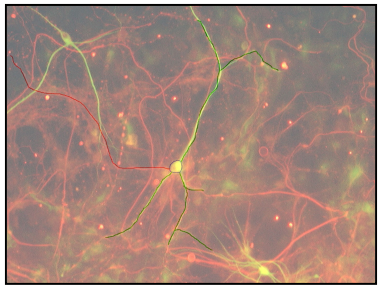
- Code 5583: Distributed Systems
  - OASES (*Ocean, Atmosphere, and Space Environmental Services*)
  - ATLOS (*Acoustic Transmission Loss Server*)
  - JWARS T-L Data Engine
  - ESME (*Effects of Sound on Marine Mammals*)
  - Ontology of Physics
  - BARS-SAF Integration (*Battlespace Augmented Reality System*) [w. 5581]
  - Swimmer Project [w. MA & D and 5580.1]

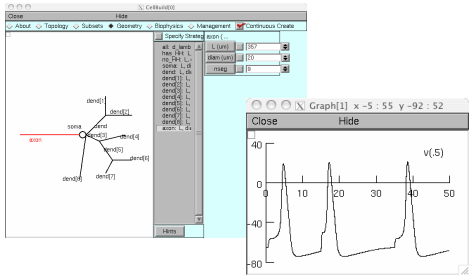
NRL 5583 M&S Research

- Vestibular Research Facility
  - Designed and built by ARTIS LTD with funding from NRL Capital Procurement Grant.
  - Laboratory is at NRL DC, Building 35.

- B[illegible]L 6930]







NRL 5583 M&S Research

- Code 5581: 3-D Virtual & Mixed Environments
  - BARS (*Battlefield Augmented Reality System*)
  - Sonar Uncertainty Visualization (completed)
- Code 5584: Intelligent Decision Systems
  - ICAPA *(Intelligent Crisis Action Planning Aid)*
  - MANET *(Mobile Ad-Hoc Wireless Networks)*
    MAS *(Multi-agent Systems)*
- Code 5585: Collaborative Engineering
  - CEE *(Collaboration Engineering Enterprise)*

BARS/SAF Integration

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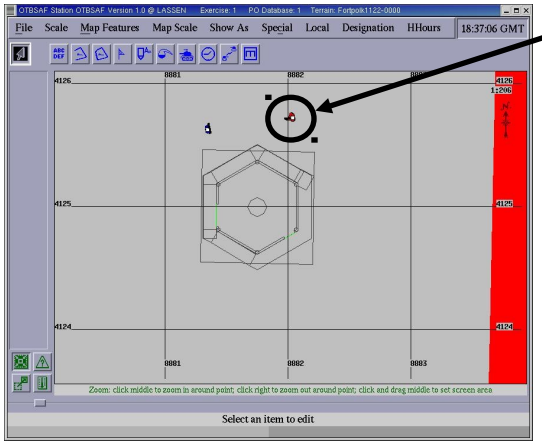
SAF & BARS Integration

- Embedded training tool developed for ARMY RDECOM
- Link Battlefield Augmented Reality System (BARS) to ModSAF-based entity simulators
  - DIS communications: OneSAF Testbed
  - HLA communications: JSAF Testbed
- BARS Bridge (gateway) provides interface for
  - SAF-based entity updates to BARS thereby allowing visualization of simulated dismounted infantrymen.
  - BARS feedback to the SAF thereby allowing interactions between SAF & BARS entities.

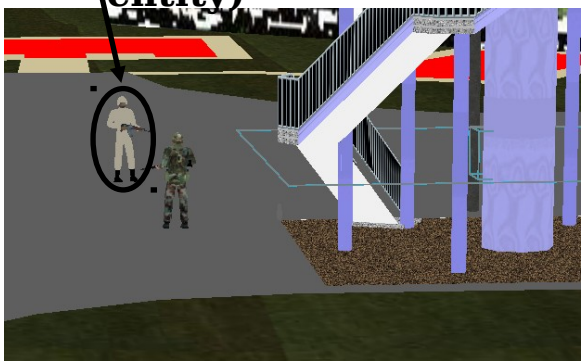
BARS AR View (DI-Guy)

OTBSAF



BARS-SAF Bridge (same DI entity)

BARS VR View



NRL 5580 M&S Capabilities

Effects of Sound on the Marine Environment (ESME)

NRL Code 5583

NRL 5583 M&S Research

ESME Overview

Objectives:

(1) Integrate software and data encompassing models for acoustic sources, the physical environment, and the behavior and sensory physiology of marine mammals.

(2) Build a modular software tool for estimating the received *acoustic time series* along an animal's track, and predicting the species-specific TTS's (*Temporary Threshold Shifts*).

Sponsors: ONR 342, ONR 321

Continuous funding FY01-FY04.

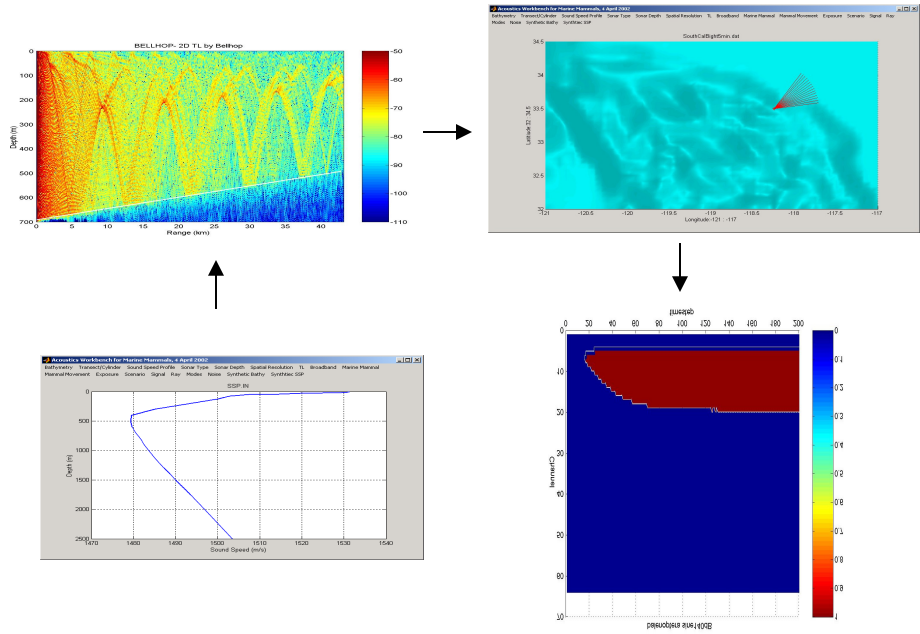
Approach:

(1) At project onset, NRL was given the task of system integration.

(2) Collect prototype software modules from ESME co-investigators.

(3) Test the individual modules, and resolve interoperability issues.

(4) Design and implement a Matlab workbench which transparently integrates the software modules, and provides an intuitive menu-driven interface for the user.



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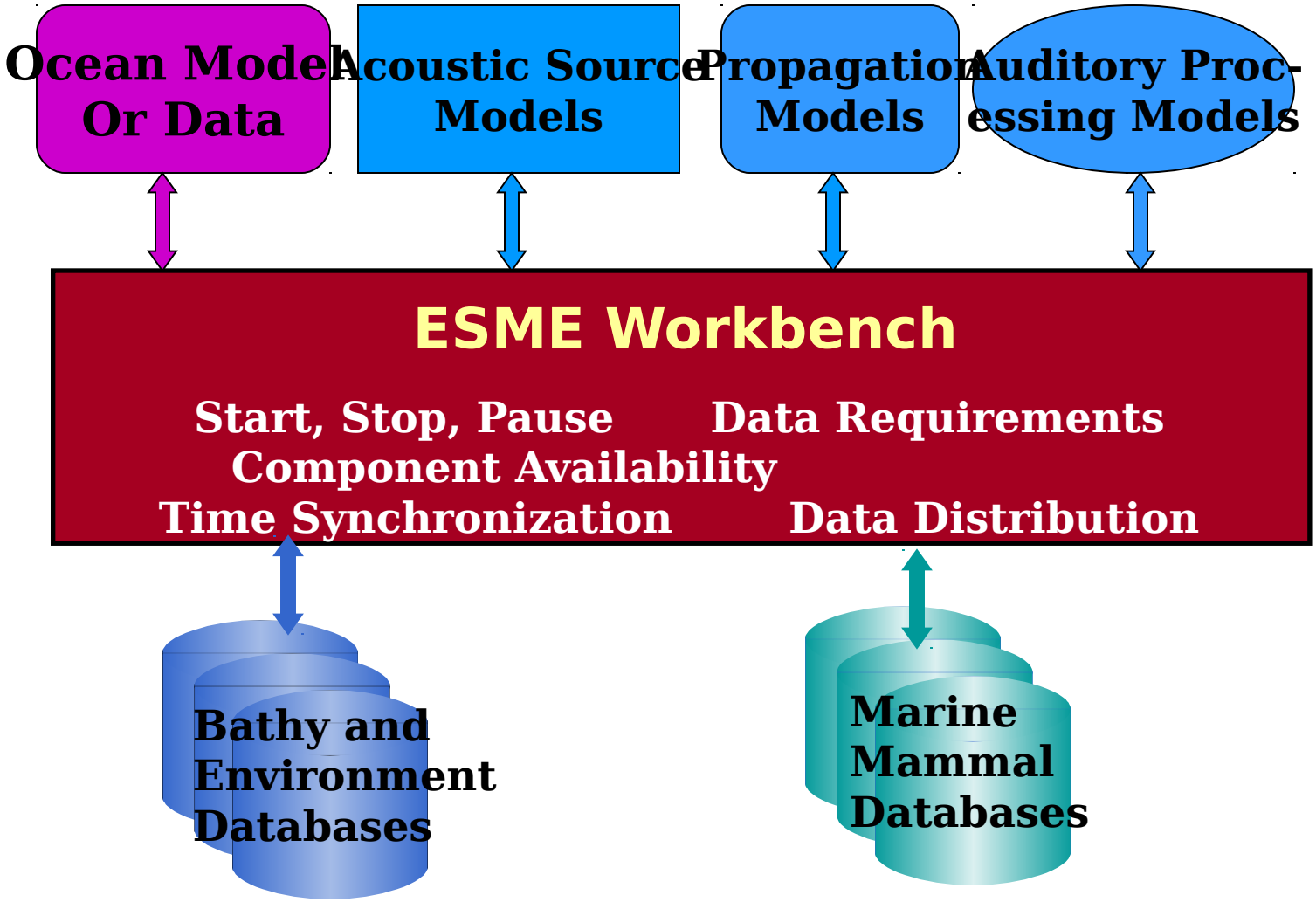
Conceptual Workbench Architecture



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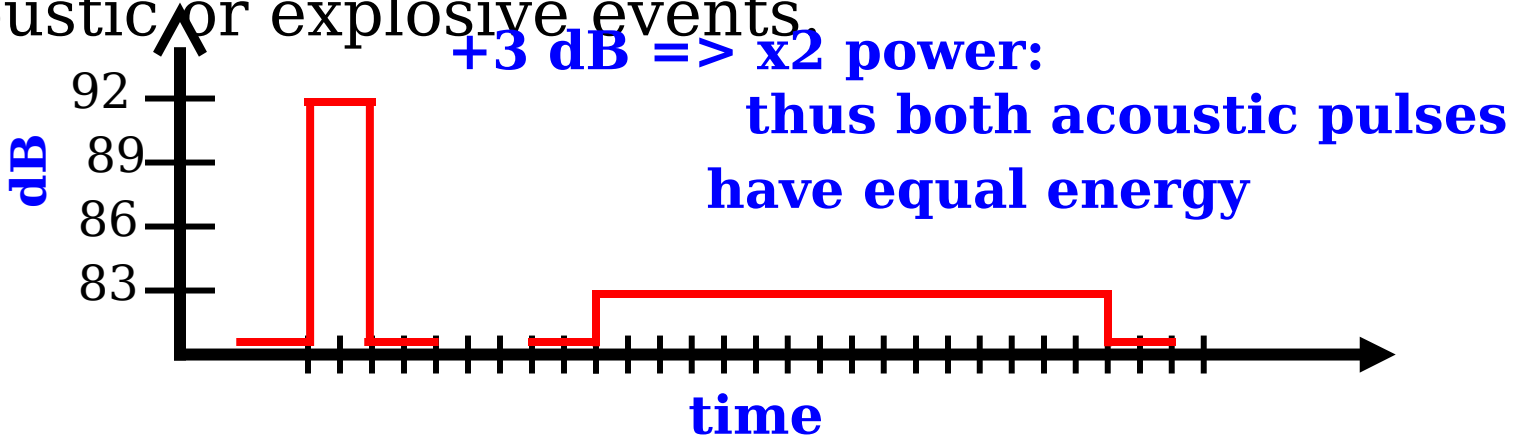
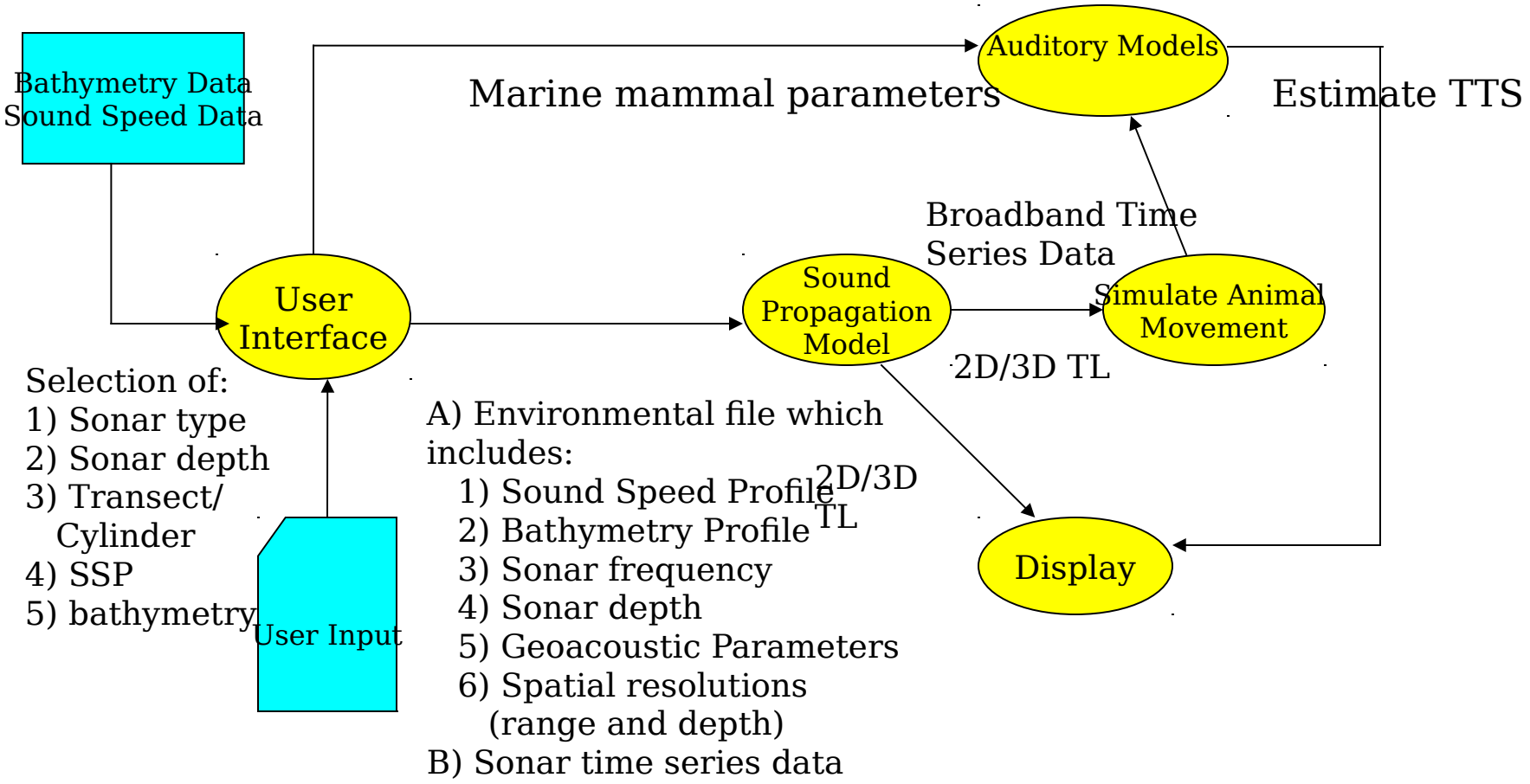
- ESME workbench approach:
  - Integrate algorithms and programs provided by domain experts - *propagation models, geophysical data, auditory models,* and *behavioral data*.
  - Predict TTS (Temporary Threshold Shift) as a function of the *received acoustic time series* (as opposed to received power levels) along the animal's tracks.
  - Identify source ranges for trauma in response to acoustic or explosive events.



NRL 5583 M&S Research



Software Components of the ESME Workbench

Contributor	Organization	Module	Language
	SAIC	Ocean Acoustic Propagation Models	FORTRAN 90 and MatLab
	Boston University	Marine Mammal Auditory System Models	MatLab
	University of Rhode Island	Geoacoustic Model	MatLab
	SPAWAR	Temporary Threshold Shift Models	MatLab
	SPAWAR	Behavior & Movement Models	Microsoft Visual C++
	Woods Hole Oceanographic Institution (WHOI)	Sound Speed Profiles	Data in text format
	WHOI/Harvard Medical School	Parameters for Auditory System Models	Matlab

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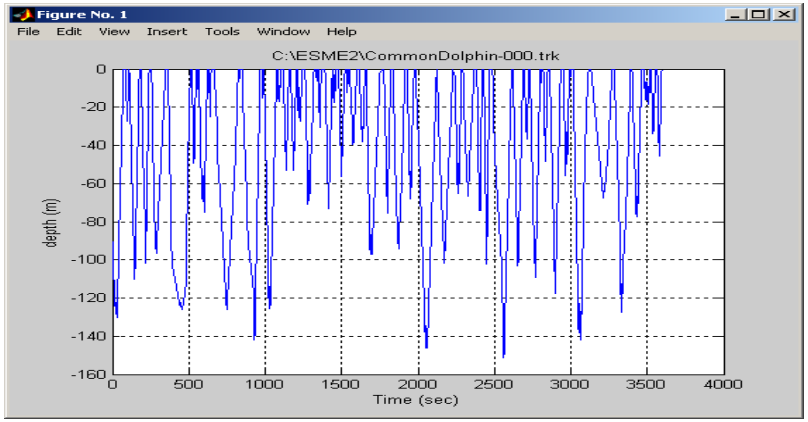
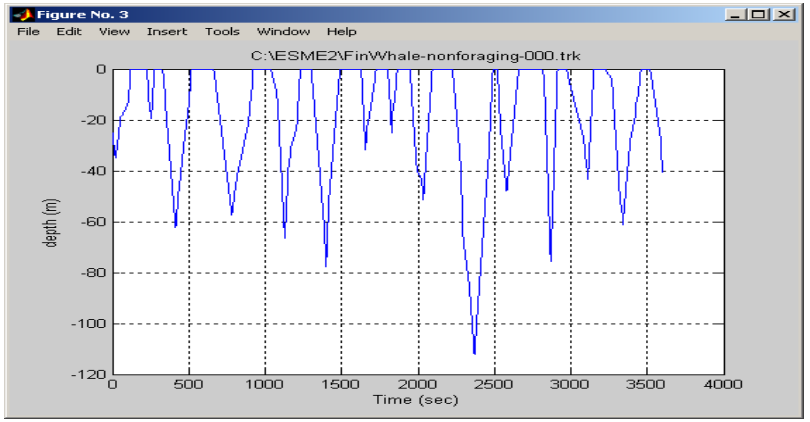
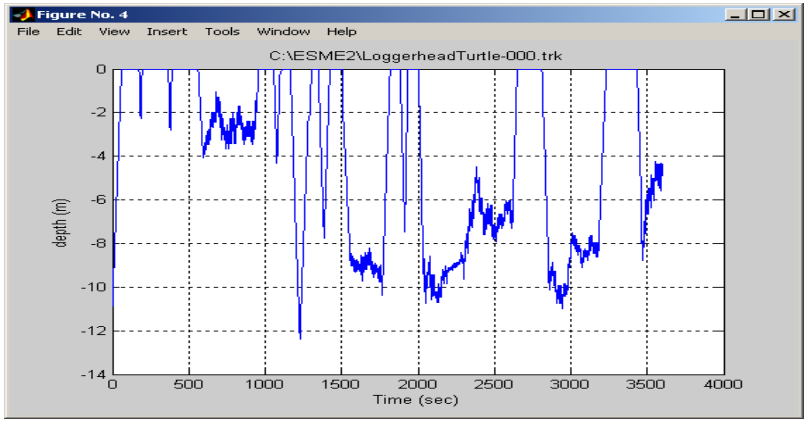
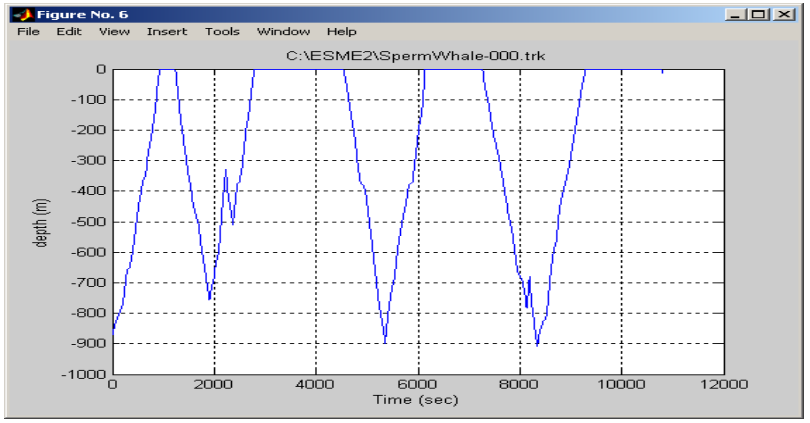
Diving Profiles of different species of marine mammals









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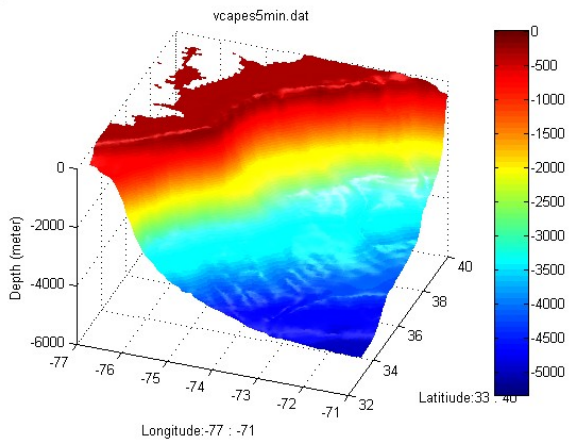
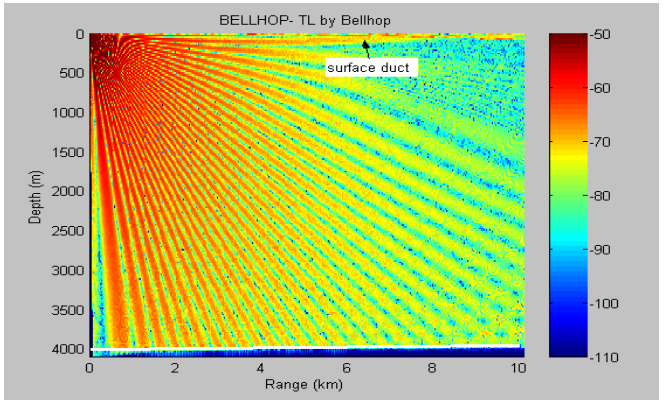
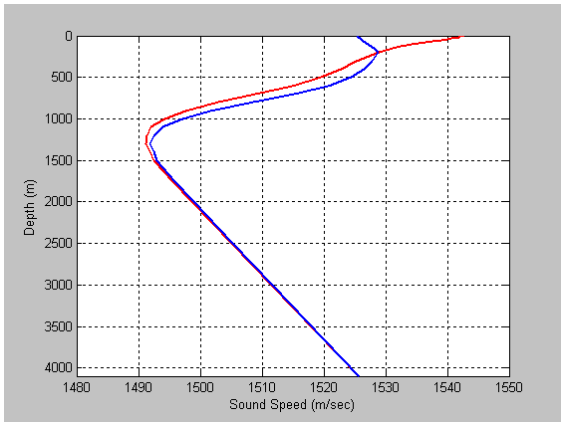
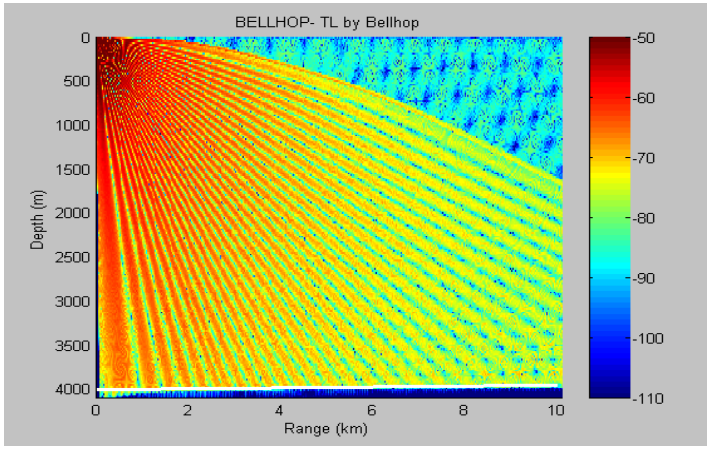
Seasonal Effects on Acoustic Fields









Simulated winter (upper right) and summer (lower right) acoustic fields in Virginia Capes

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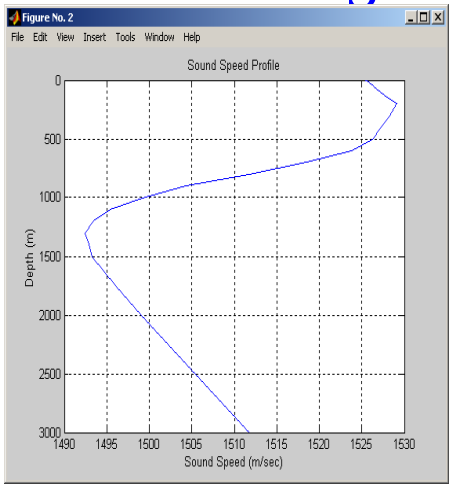
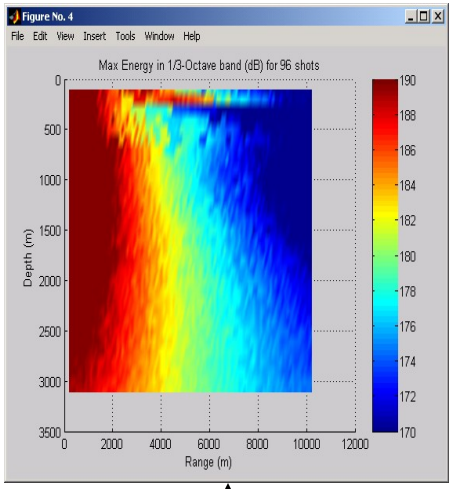
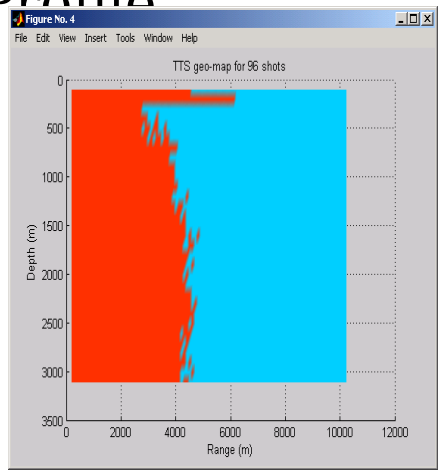
Training Exercise Analysis for Naval Facilities Engineering Command (Atlantic Fleet)



Sound Velocity Profile



Distribution of Maximum Energy (dB) of the 1/3-Octave bands for 96 consecutive shots.



Predicted zone for TTS (Temporary Threshold Shift) for 96 shots (using the historical TTS criteria from the Churchill ship shock trials).

Approach:

- *Select TTS criteria.*
- *Use REFMS non-linear shockwave propagation model to model propagation of explosive events.*

ESME References

1. Shyu, Haw-Jye and Roger Hillson, “A Software Workbench for Estimating the Effects of Cumulative Sound Exposure for Marine Mammals” accepted for publication in special ESME issue of the *IEEE Journal of Oceanic Engineering*.

2. Shyu, Haw-Jye and Roger Hillson, "Integrating Ocean Acoustic Propagation Models and Marine Mammal Auditory Models," *Oceans 2002 MTS/IEEE,* Biloxi MS, 29-31 October 2002.

NRL 5580 M&S
Capabilities

Providing an Improved Real-Time Natural Environment for the Navy's Fleet Battle Experiments with OASES and ATLOS

RADM Hart's Brief Before Congress (March 18, 2004)

"JSAF also integrates the Ocean and Atmospheric Services Environmental Simulation (OASES) that provides a coupled ocean atmospheric model needed to create a realistic environment for simulated objects to interact in concert with physical kinetics and sensor performance … This function is required to effectively support the integration of LVC; and without the capability, a fair fight within the LVC environment cannot exist. OASES was developed in a cooperative program sponsored by the Defense Modeling and Simulation Office, the Navy Warfare Development Command, the Naval Research Laboratory, and the Navy's Oceanographer."

Problem: Level Playing Field

- Increasingly large modeling and simulation federations of disparate federates for Training and Experimentation require a consistent natural environment
- Consistent natural environment is necessary in modeling and simulation-based Acquisition to ensure meaningful comparisons of performance

Technical Challenge: Robust Environmental Server

- Composable (HLA-compatible, EDCS)
- Useable Graphical User Interface (supports operation in a variety of M&S applications)
  - METOC operator
  - Training Referee
- Flexible (supports subscriptions, and point and line-of-sight queries)
- Supports merged datasets
- Supports Web Service Interface

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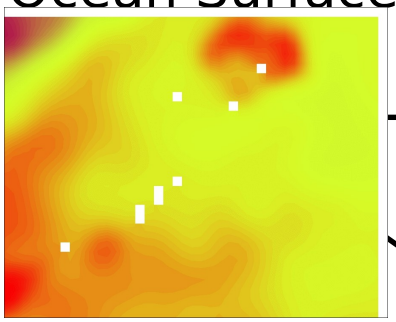
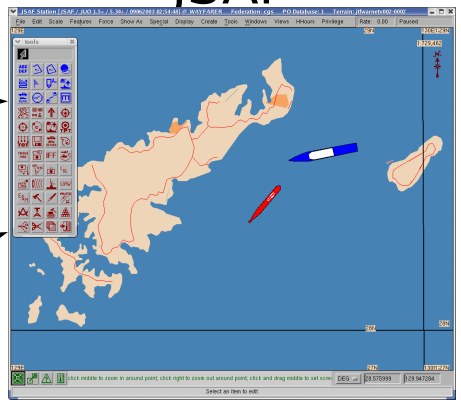
Environmental Impact on Simulation Scenario

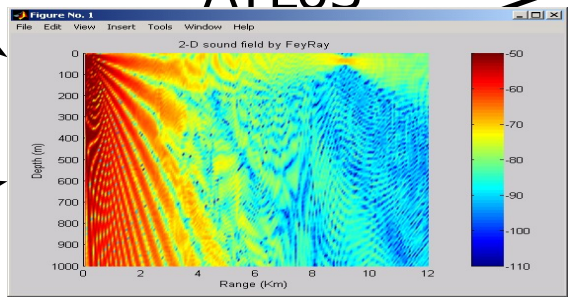
Ocean Surface



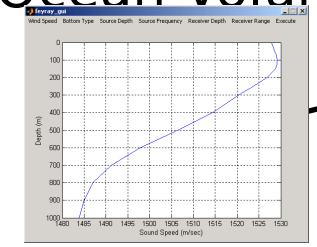
JSAF



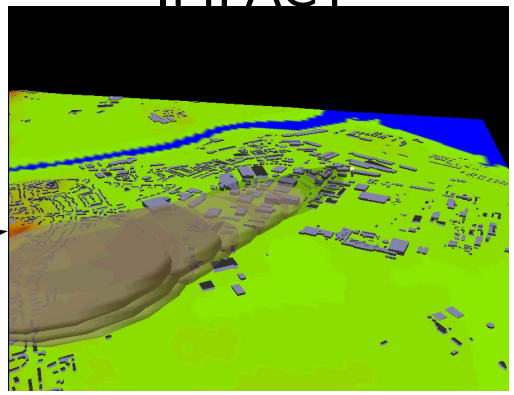
ATLoS



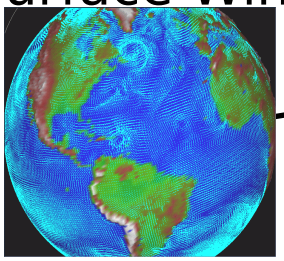
Ocean Volume



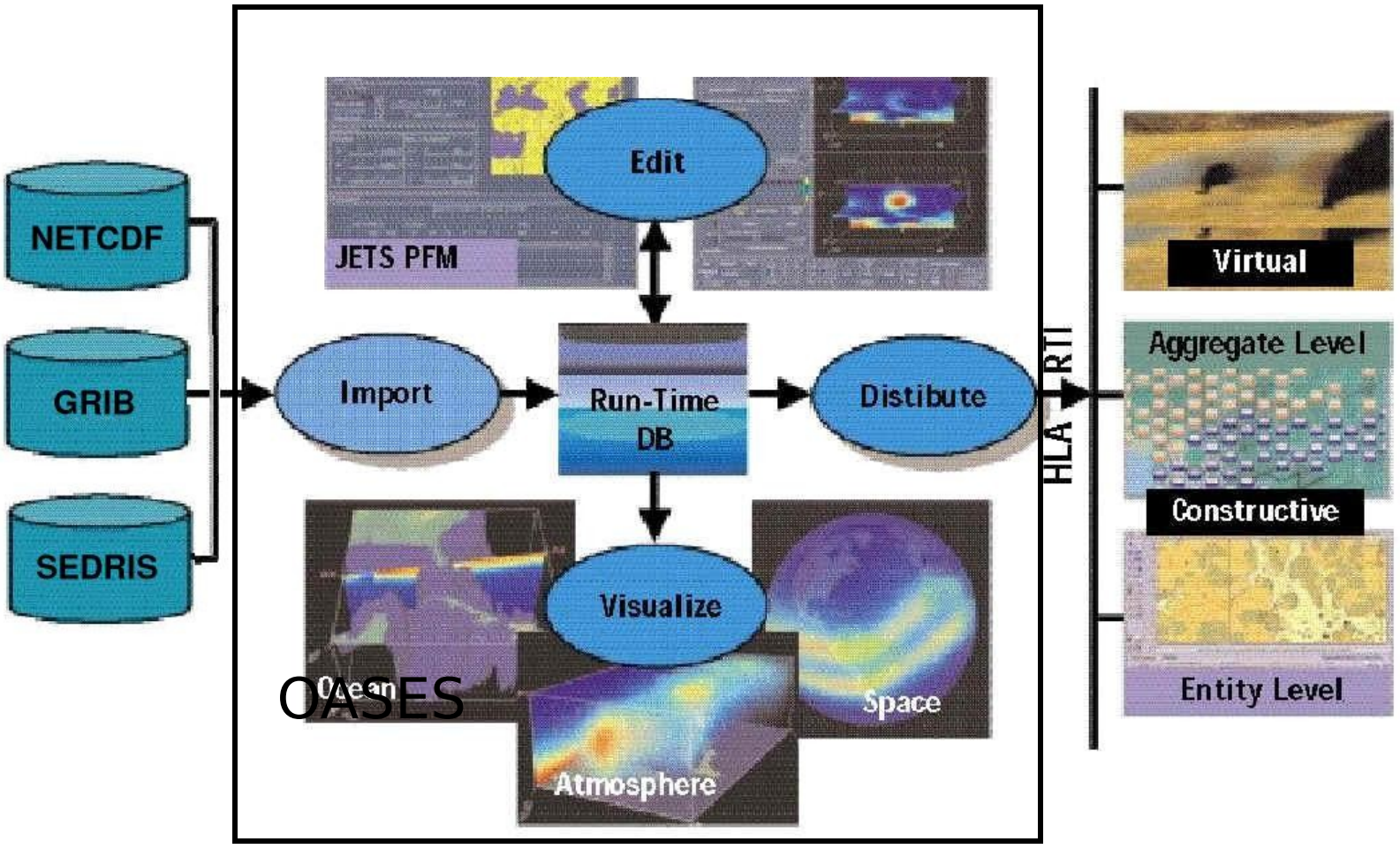
IMPACT



Surface Winds



Ocean Atmosphere Space Environmental Services (OASES)



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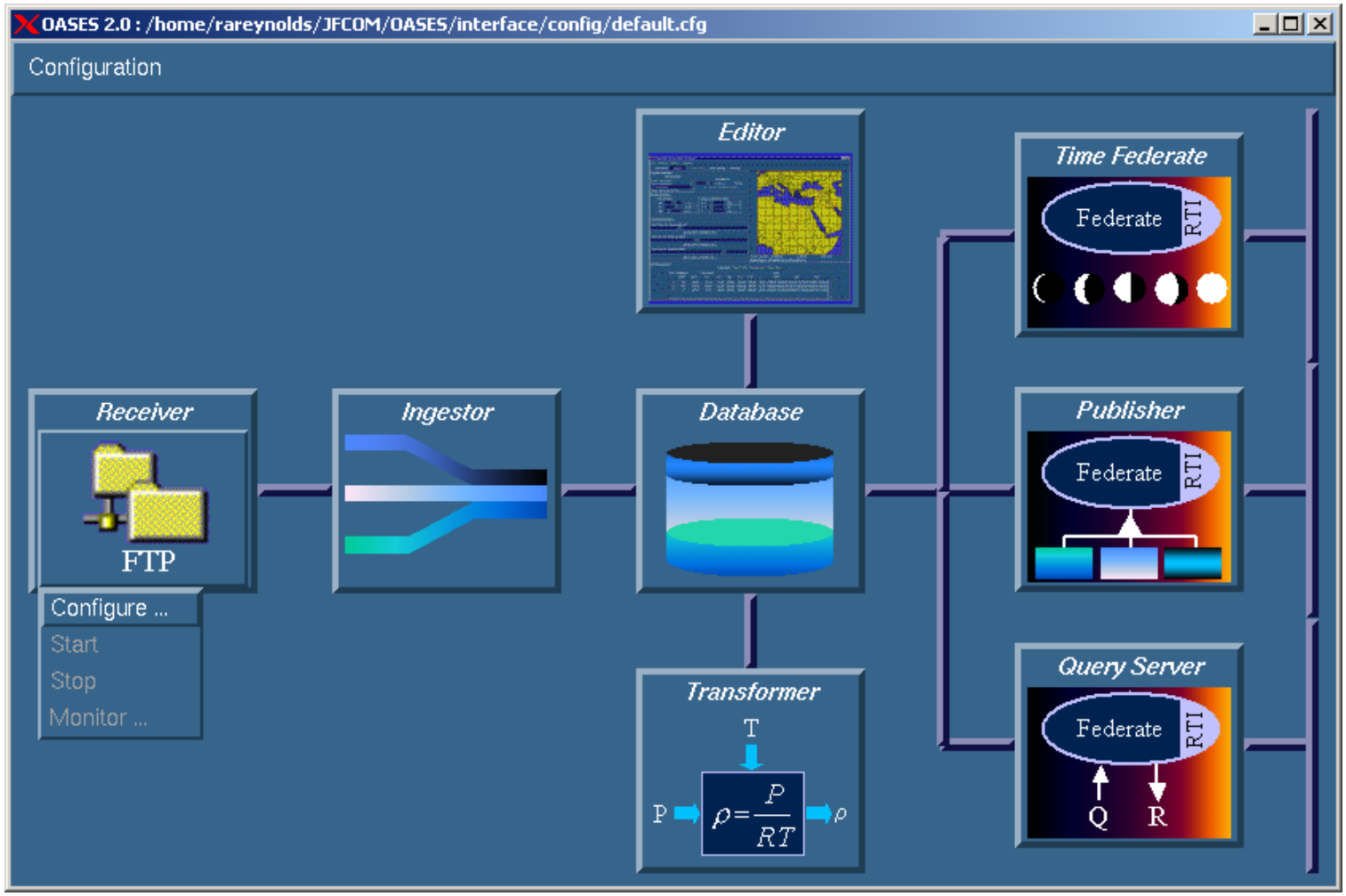
OASES Main GUI



Impact

- Training and Experimentation
  - OASES is central to DOD Training Transformation focus
    - Fair fight in Navy's Continuous Training Environment
- OASES Query Server needed in a variety of M&S Applications
  - Navy Aviation Simulation Master Plan (NASMP)
  - Joint National Training Capability (JNTC)
- Acquisition
  - Multi-Mission Maritime Aircraft (MMA)
  - Air Common Sensor (ACS)

OASES Users

- Active OASES Users Group
  - NavAir
  - Navy Warfare Development Command
  - Dugway Proving Grounds
  - Joint Forces Command (JFCOM)
- Configuration Management by JFCOM
  - Release Authority
  - Single remote source code repository accessible by all developers

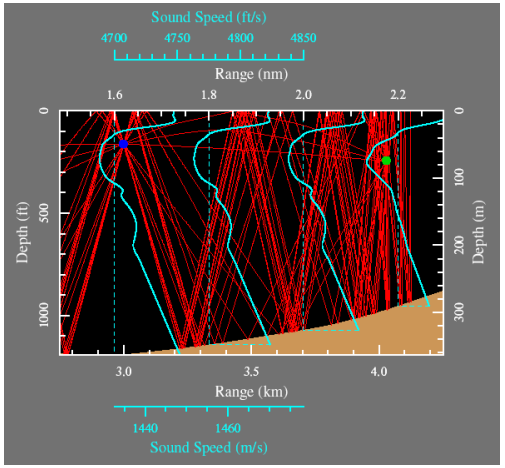
ATLoS

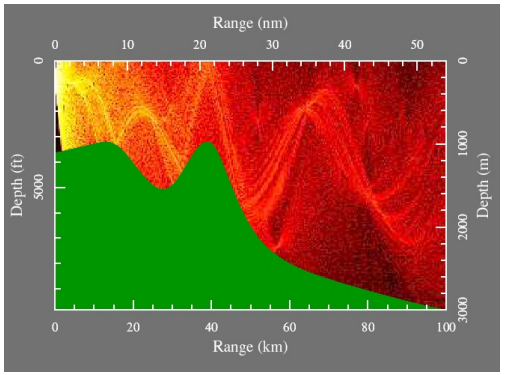
(Acoustic Transmission Loss Server)

- Receives, queues requests; computes transmission loss with FeyRay; sends response
- Use some JSAF libraries, CTDB, Linux OS
- High Level Architecture (HLA) based Server: A Separate Federate
- Included in FBE cvs-tree

Acoustic Propagation Model

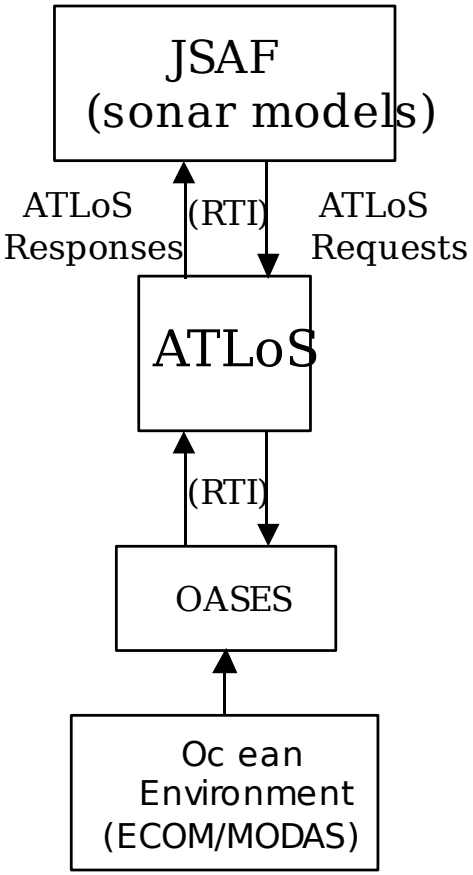
- Testing: typical requests for multi-km ranges
- FeyRay-Fast Gaussian Ray Beam code
- HFBL bottom
- Bathymetry from Marine Trackline DB and ETOPO5





Dataflow

- JSAF models: Northrup Grumman
  - (Logicon)
- NRL: ATLoS
- OASES Server: Northrup Grumman
  - (TASC)
- HydroQual: Ocean Environment



NRL 5583 M&S Research

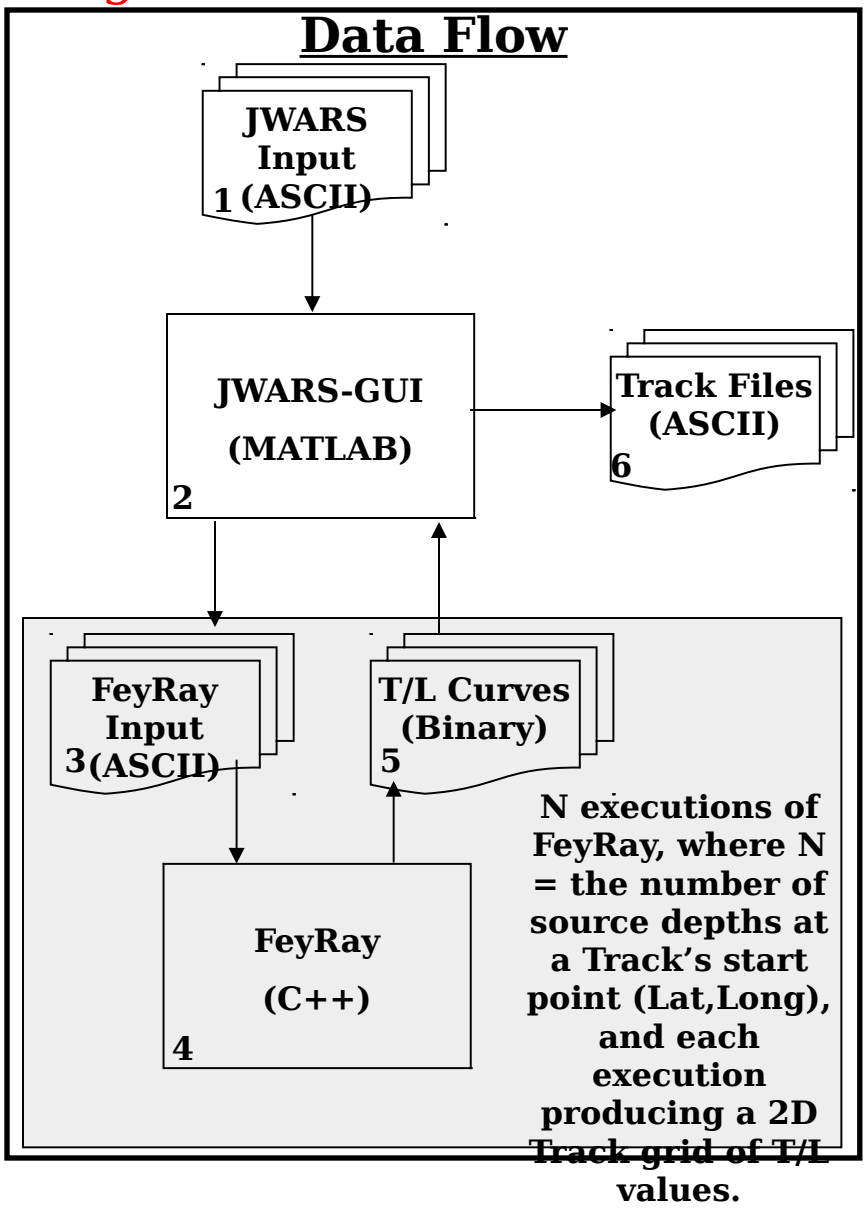
JWARS T/L Data Engine

NRL 5583

NRL 5583 M&S Research

JWARS T/L Data Engine

- JWARS Input from JHU APL
  - Track Files
  - Bathymetry, bottom type, SSP
- JWARS-GUI generates Transmission Loss (T/L) track files
  - Seasonal Tracks (14672 total tracks)
    - Summer97 (188 baseline and 8161 random tracks)
    - Winter98 (155 baseline and 6168 random tracks)
  - Average Track
    - 500 range grid points
    - 20 depths (source & receiver)
    - 15 frequencies
  - Speed & Size
    - 60 sec/track => (244+ hrs) total
    - 1 MB/track => (14+GB) total
    - $3x10^6$ T/L values/track => $4.4x10^{10}$ T/L values total calculated


Data Flow
JWARS Input 1 (ASCII)
JWARS-GUI (MATLAB) 2
Track Files (ASCII) 6
FeyRay Input 3(ASCII)
T/L Curves (Binary) 5
FeyRay (C++) 4
N executions of FeyRay, where N = the number of source depths at a Track's start point (Lat,Long), and each execution producing a 2D Track grid of T/L values.

NRL 5580 M&S Capabilities

Swimmer Project

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NRL 5583 M&S Research

SWIMMER PROJECT

- **Humans are environmentally sensitive system elements**
- **Human capabilities and limitations can have significant impacts on mission performance.**
- **Simulation fidelity requires representation of environmental impact on humans**

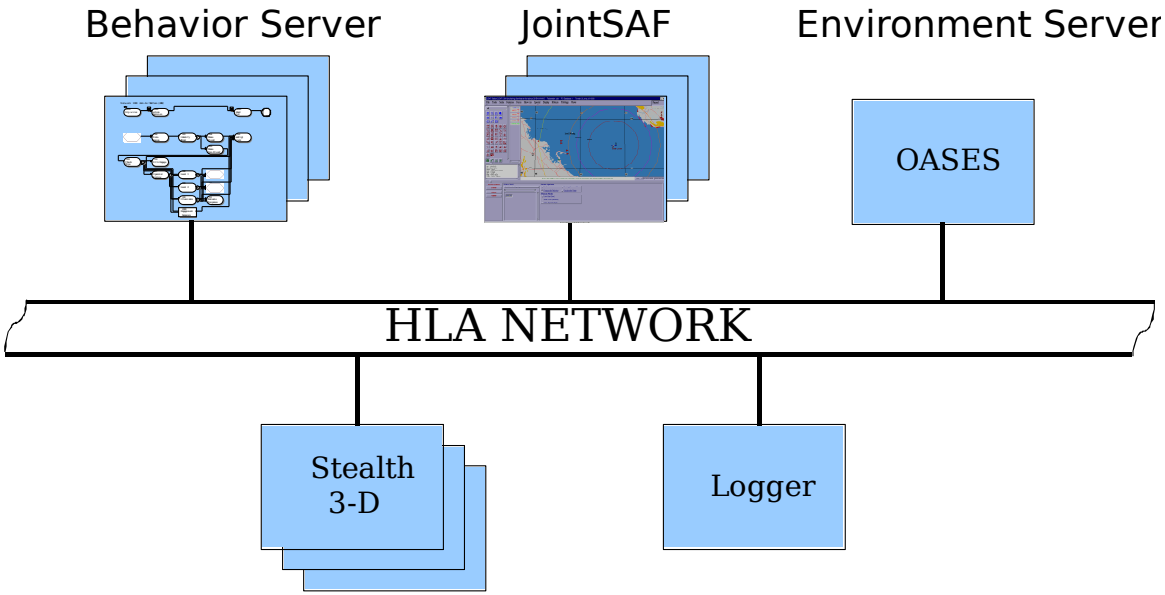
NRL 5583 M&S Research

SWIMMER PROJECT

- **Explosive Ordinance Disposal (EOD) divers, from EOD -TEU -TWO, Ft Story, VA, and, EODMU FIVE, Sasebo, Japan acted as Subject Matter Experts (SMEs)**
- **EOD task and mission parameters were identified in order to create a reasonable swimmer entity for mine countermeasure missions (MCM) within the Computer Generated Forces (CGF).**
- **NRL used MicroAnalysis and Design to develop a swimmer task flow charts and a discrete event simulation federate for M&S with Joint Semi-Automated Forces (JSAF) using their Micro Saint tool.**
- **Interaction with Ocean, Atmospheric, and Space Environmental Services (OASES) was developed for serving swimmer entities.**

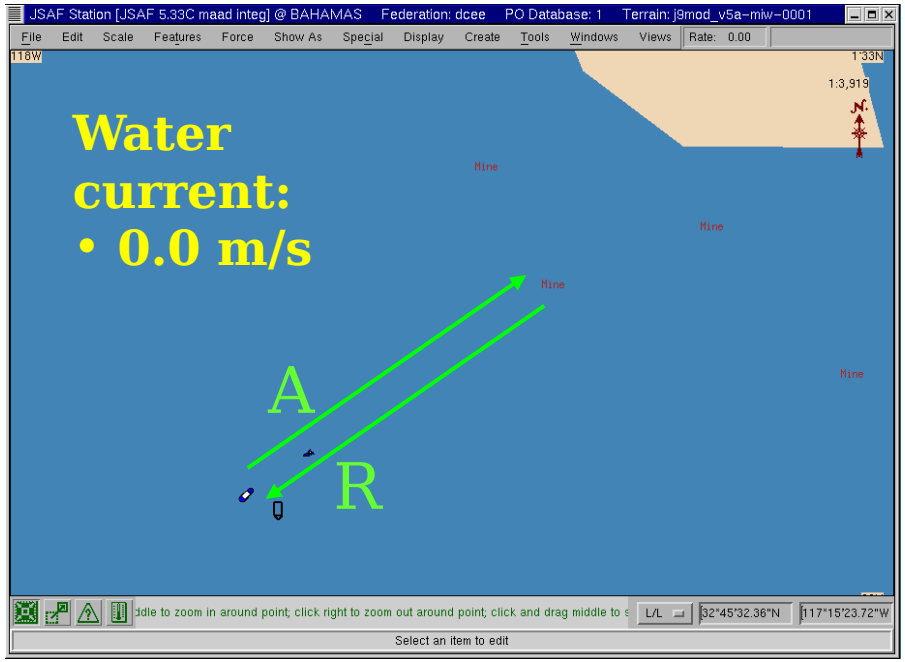
SWIMMER PROJECT

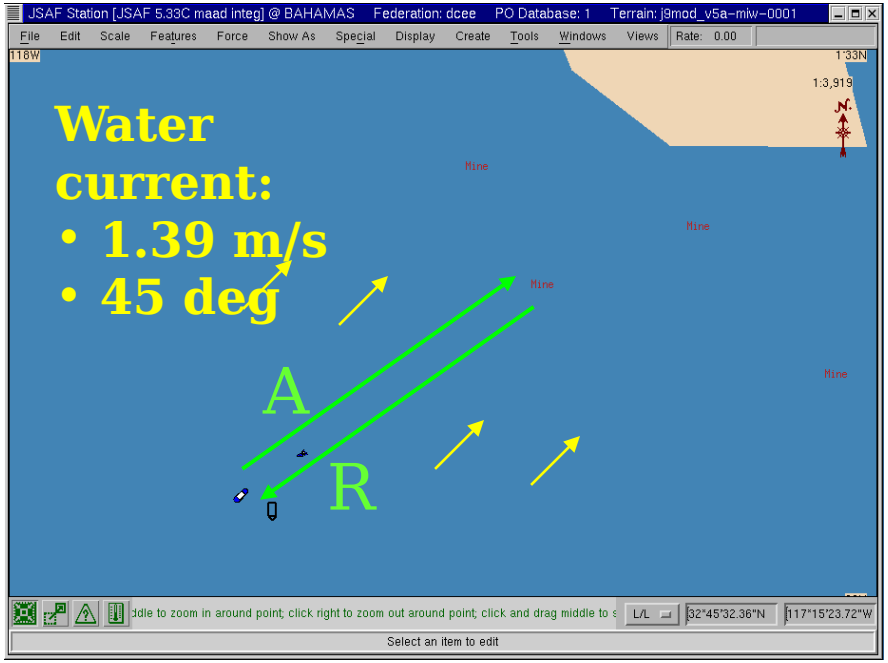
NRL Swimmer Federation Configuration



NRL 5583 M&S Research

Swimmer Behavior Test Results





Swim Speed: 1.5m/s Depth: 5m

Water Current	Approach Time(A)	Approach Air Used	Time Spent at mine	Air Used placing charge	Return Time(R)	Return Air Used
0.0 m/s	257sec	175psi	282sec	55psi	257sec	175psi
1.39m/s, 45degrees	133sec	91psi	272sec	53psi	3,465sec	2,361psi

Less time and air used Swimming with current.

A lot more time and air used swimming against the Current.

Reporting and Future Direction

- Demonstrated at the Inter-service / Industry Training, Simulation, & Education Conference (I/ITSEC) in November 2003
- Paper presented at Behavior Representation in Modeling and Simulation (BRIMS)
- Recommended future directions to further enhance the fidelity of the swimmer entity
  - Represent other physiological variables
    - Fatigue
    - CO_2 buildup and the effects on behavior
    - How water temperature alters performance
    - Relationship between equipment and performance during missions

NRL 5580 M&S
Capabilities

Towards an Ontology of Physics

Standardizing model descriptions

(The vision: we've only just begun.)

Naval Research Lab, and
GARD Assoc

Why Ontologies?

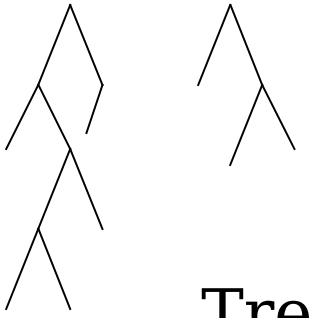
- An Ontology provides a framework for metadata to describe models
- Meaningful interoperability requires machine readable metadata, expressing modeling concepts
  - Intelligent Agents need ontologically based metadata
- Example: HLA does not support metadata
  - HLA supports executable-to-executable communication
  - Limited semantics are expressed in the computer
  - Agreements and assumptions stored primarily in human memory, accessible only to a few

Why a Standard Ontology?

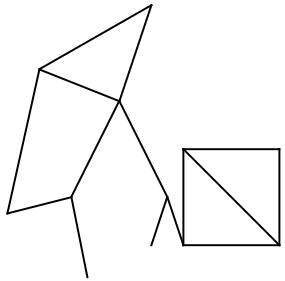
- Can't yet trust "black" boxes
  - Need to know internals
- Documentation, transparency
  - Enables informed use of models
- Automated "understanding"
  - Enables search, retrieval of models
  - What "html" did for information accessibility, OoP can do for physics-based model accessibility
- Composability
  - Facilitate meaningful model composition
  - Not necessarily "plug-and-play"

Semantic Relationships: Ontologies & Taxonomies

- Ontology: Concept vocabulary + rules, constraints + relationships
- Taxonomy implies hierarchy (tree)
- Ontology is a web (graph) of *relationships*
- Semantic relationships MAY form a taxonomy in special cases
- Graphs (webs) can represent any relationship topology



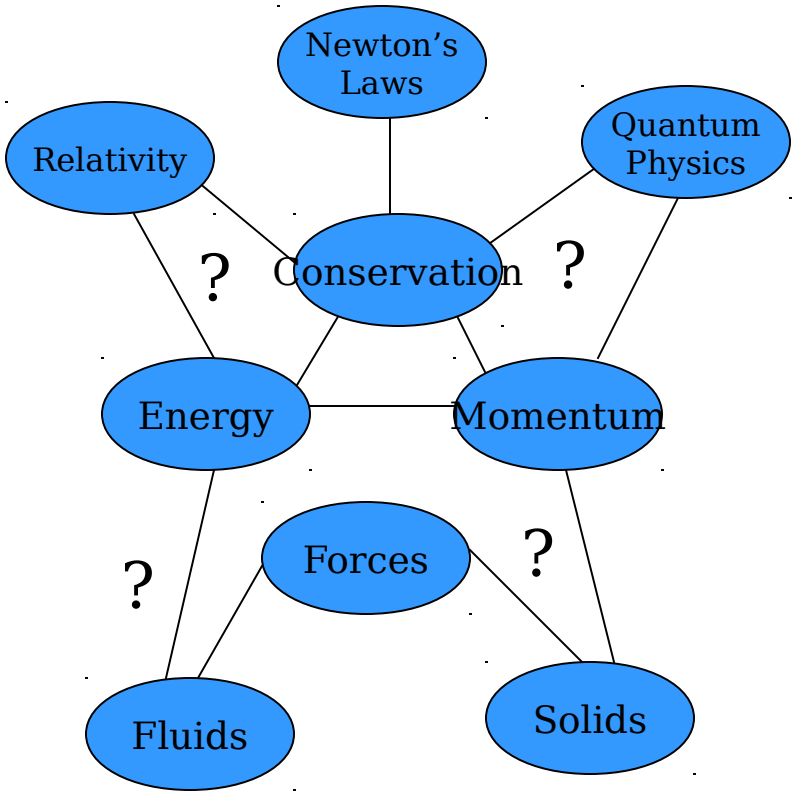
Trees



Graph / Web

Physics-Based Modeling Concepts, Relationships

Ontology of Physics

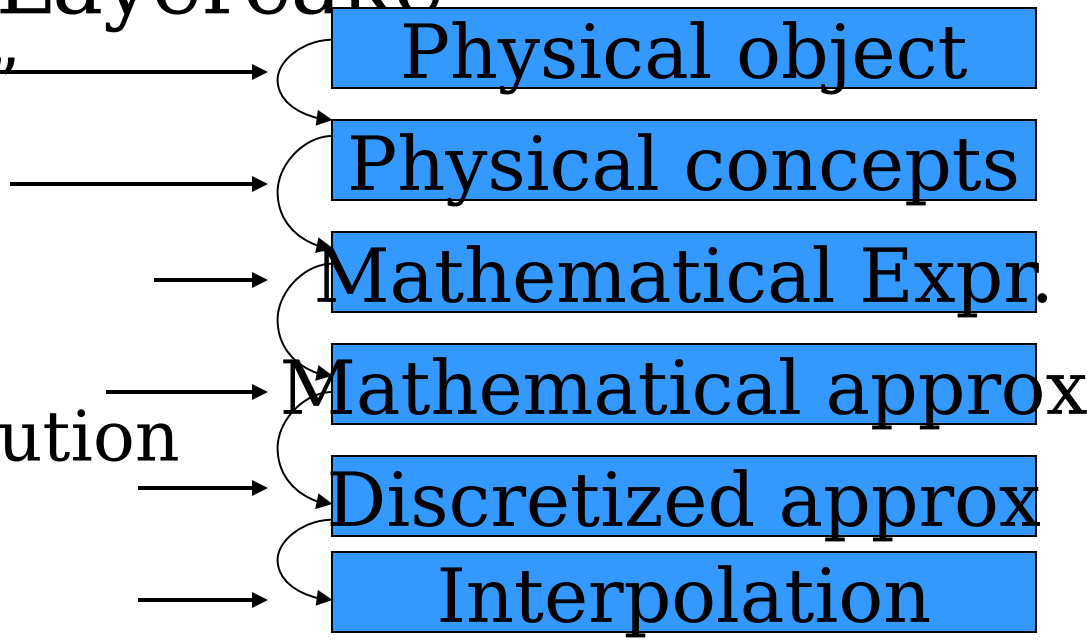


An Ontology of Physics (OoP)

- Meta-Physics, not metaphysics!
  - Applied physics: not philosophy, not physics research
  - The language we must use to describe physical concepts used in models
- Standardized concepts and constructs for standardizing physical descriptions
- Applicable to physics-based models

A Physics-Based Model Ontology Layercake

- The “referent”
- The Physics
- Language of physics
- The easier solution
- Let’s get an answer!
- The next guy’s grid



Each layer to layer, downward transition is **informal**, **one-to-many**

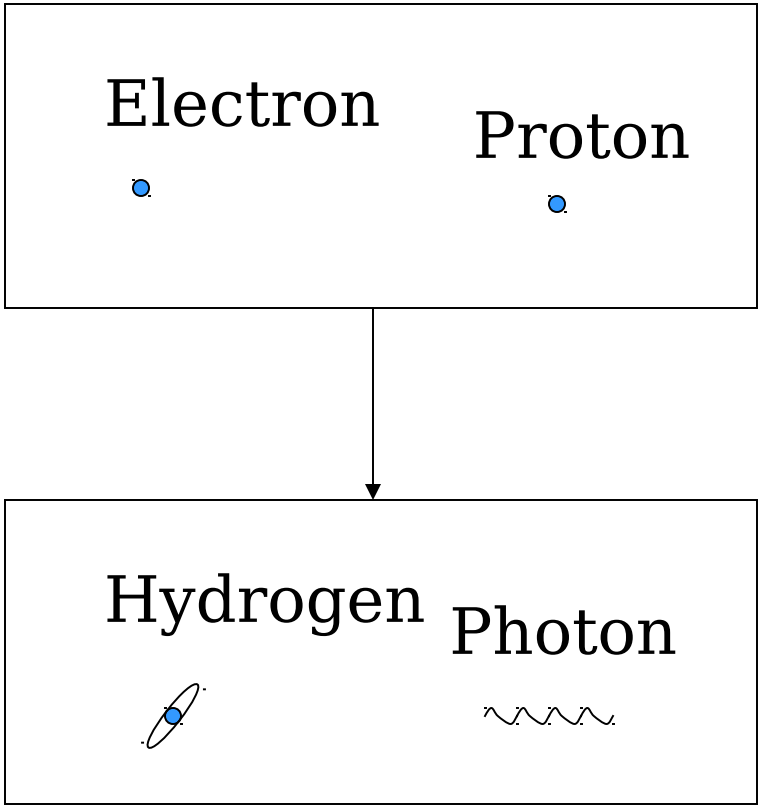
Can we infer the Physical Concept from the last layer? **No!**

Fundamental Physical Concepts

- Physical Object (PO) - fundamental concept
  - Has mass, energy, momentum, charge, etc
    - Conserved when not interacting
  - Has force interaction (relationship) with other POs - momentum exchange
  - May be composed with other POs
    - Conservation laws apply
- Conservation may be newtonian, relativistic, quantum mechanical
- Reference Frame depends on conservation rule

Composing Physical Objects

- Physical objects combine - composition
- Model composition is not simple "plugging together"
- Division between Internal and External forces and motion



Marking Up

- Physics Concept: an applied force causes a mass to accelerate - (marking up a math statement)

<PhysObj.force unit=newton> F
</PhysObj.force> =
<PhysObj.mass unit=kilogm> m
</PhysObj.mass> *
<PhysObj.acceleration> a
</PhysObj.acceleration>

- Math Concept: Equation - A three dimensional real valued vector, F, is equal to the scalar, m, multiplied by the three dimensional real valued vector, a.
- Numerical (discrete math) Concept ...

Tools, Solution Pieces

- MathML - Mathematical Markup Language, OpenMath extension
  - W3C standards; broad community of interest
- There are authoring tools that support math formalism
  - Examples: Mathematica, Maple, MuPad
  - Look for support for: objects; discrete methods
  - Many use MathML + OpenMath as interchange standard
- PyCES and PhysicsML
  - Nascent effort at an Ontology of Physics

Benefits

- Facilitates correct model composition
  - By model composers
  - Semantics provided by metadata
  - Improved speed, efficiency of composition
- Open access to models by non-experts
  - Search and retrieval
  - Intelligent agent access
- Animation engines and improved dead-reckoning
  - Interactive examination of dynamical models
- Automation of documentation
  - Authoring tools provide
- Decision aids for simulation builders
  - Anticipate environmental effects in simulation